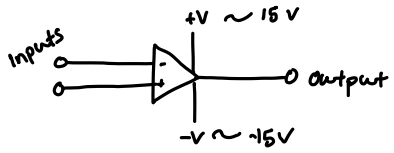
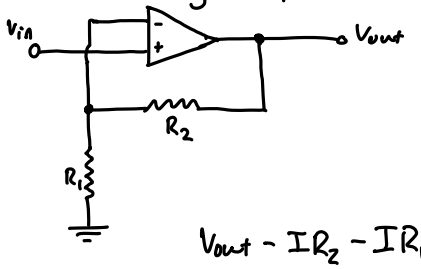
Op Amps



If + input > - input
then output is positive

If - input > + input
then output is negative

Noninverting Amplifier Negative Feedback



$V_{out} - IR_2 - IR_1 = 0$

$V_{out} = I(R_1 + R_2)$

$V_{out} = \frac{V_{in}}{R_1}(R_1 + R_2)$

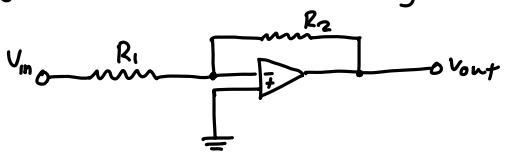
$V_{out} = V_{in} + V_{in}\frac{R_2}{R_1}$

$V_{out} = V_{in}\left(1 + \frac{R_2}{R_1}\right)$

$V_{in} - IR_1 = 0$

$I = V_{in}/R_1$

Negative Feedback Inverting Amplifier



When there is negative feedback
2 Golden Rules:

—> Inputs do whatever is necessary to make Voltage difference across inputs Zero

$V_+ = V_-$

—> Inputs draw no current

$V_+ = 0 = V_-$

$V_{in} - IR_1 = 0$

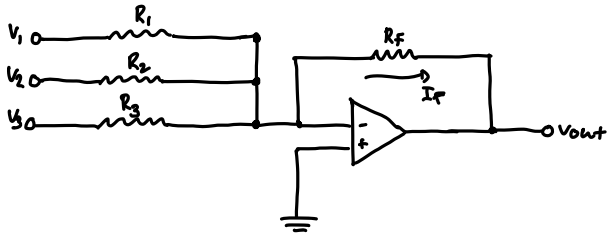
$I = V_{in}/R_1$

$0 - IR_2 = V_{out}$

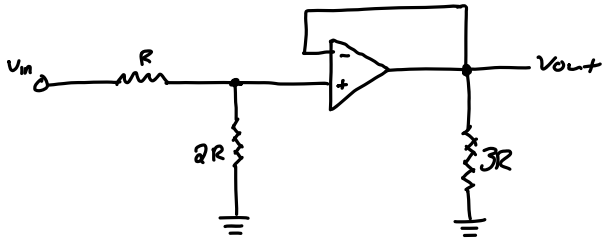
$-IR_2 = V_{out}$

$V_{out} = -\frac{R_2}{R_1}V_{in}$

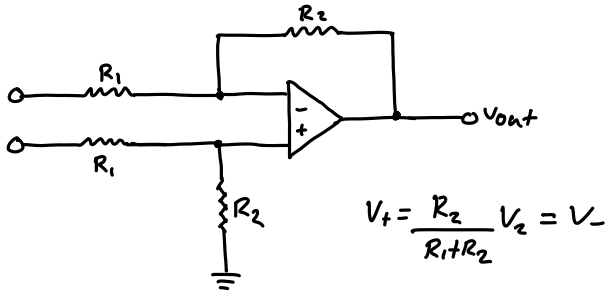
This is called an inverting amplifier.



Inverting summation amplifier



$V_{out} \approx \frac{R_2}{R_1+R_2}V_{in} \simeq \frac{2}{3}V_{in}$



$V_+ = \frac{R_2}{R_1+R_2}V_2 = V_-$

$V_1 - IR_1 = V_-$

$V_1 - IR_1 = \frac{R_2}{R_1+R_2}V_2$

$\frac{1}{R_1}\left(V_1 - \frac{R_2V_2}{R_1+R_2}\right) = I$

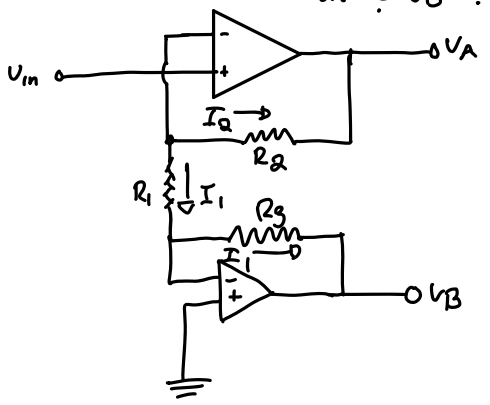
$V_{out} = V_- - IR_2$

$= \frac{R_1R_2V_2}{(R_1+R_2)R_1} = \frac{R_2}{R_1}\left(V_1 - \frac{R_2^2V_2}{R_1+R_2}\right)$

$= \frac{R_1R_2V_2 - R_2(R_1+R_2)V_1 + R_2^2V_2}{R_1(R_1+R_2)}$

$V_{out} = \frac{R_2(R_1+R_2)V_2 - R_2(R_1+R_2)V_1}{R_1(R_1+R_2)}$

V_A & V_B ?



$$V_{in} - I_2 R_2 = V_A$$

$$V_{in} - I_1 R_1 - I_1 R_3 = V_B$$

$$V_{in} - I_1(R_1 + R_3) = V_B$$

$$V_{in} - \frac{V_{in}}{R_1}(R_1 + R_3) = V_B$$

$$V_{in} - V_{in} - V_{in}\frac{R_3}{R_1} = V_B$$

$$V_{in} - \left(\frac{-V_{in}}{R_1}\right) R_2 = V_A$$

$$V_A = V_{in} + \frac{V_{in} R_2}{R_1}$$

$$V_{in} - I_1 R_1 = 0$$

$$I_1 = \frac{V_{in}}{R_1} \qquad I_2 = -I_1 = -\frac{V_{in}}{R_1}$$

$$V_B = -\frac{V_{in} \cdot R_3}{R_1}$$

$$V_A = V_{in}\left(1 + \frac{R_3}{R_1}\right)$$